

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
24 April 2003 (24.04.2003)

PCT

(10) International Publication Number  
**WO 03/034544 A1**

(51) International Patent Classification<sup>7</sup>: **H01Q 9/04,**  
1/24, 5/00

(21) International Application Number: PCT/EP01/11912

(22) International Filing Date: 16 October 2001 (16.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): **FRAC-**  
**TUS, S.A.** [ES/ES]; Alcalde Barnils, Edificio Testa, Mò-  
dulo C, 3<sup>o</sup>, Parque Empresarial Sant Joan, 08190 Sant Cu-  
gat Del Valles, Barcelona (ES).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **QUINTERO**  
**ILLERA, Ramiro** [ES/ES]; Alcalde Barnils, Edificio  
Testa, Mòdulo C, 3<sup>o</sup>, Parque Empresarial Sant Joan,  
08190 Sant Cugat Del Valles, Barcelona (ES). **PUEENTE**

**BALIARDA, Carles** [ES/ES]; Alcalde Barnils, Edificio  
Testa, Mòdulo C, 3<sup>o</sup>, Parque Empresarial Sant Joan, 08190  
Sant Cugat Del Valles, Barcelona (ES).

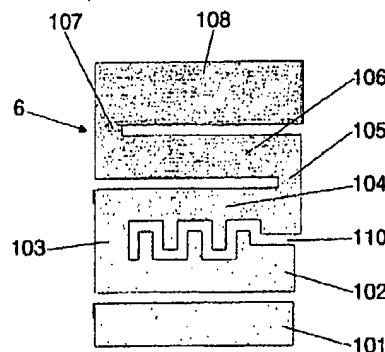
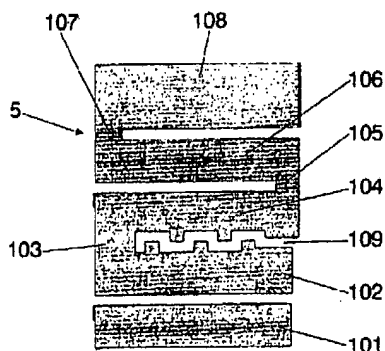
(74) Agents: **CARPINTERO LOPEZ, Francisco** et al.; Her-  
rero & Asociados, S.L., Alcalá, 35, 28014 Madrid (ES).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,  
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,  
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,  
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,  
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,  
MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI,  
SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU,  
ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian  
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European  
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,

[Continued on next page]

(54) Title: MULTIBAND ANTENNA



(57) Abstract: The present invention relates generally to a new family of antennas with a multiband behaviour, so that the frequency bands of the antenna can be tuned simultaneously to the main existing wireless services. In particular, the invention consists of shaping at least one of the gaps between some of the polygons of the multilevel structure in the form of a non-straight curve, shaped in such a way that the whole gap length is increased yet keeping its size and the same overall antenna size. Such a configuration allows an effective tuning of the frequency bands of the antenna, such that with the same overall antenna size, said antenna can be effectively tuned simultaneously to some specific services, such as for instance the five frequency bands that cover the services AMPS, GSM900, GSM1800, PCS1900, UMTS, Bluetooth<sup>TM</sup>, IEEE802.11b, or HyperLAN.

WO 03/034544 A1

**WO 03/034544 A1**



IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**Published:**

*with international search report*

**MULTIBAND ANTENNA****OBJECT AND BACKGROUND OF THE INVENTION**

- 5 The present invention relates generally to a new family of antennas with a multiband behaviour. The general configuration of the antenna consists of a multilevel structure which provides the multiband behaviour. A description on Multilevel Antennas can be found in Patent Publication No. WO01/22528. In the present invention, a modification of said multilevel structure is introduced such
- 10 that the frequency bands of the antenna can be tuned simultaneously to the main existing wireless services. In particular, the modification consists of shaping at least one of the gaps between some of the polygons in the form of a non-straight curve.
- 15 Several configurations for the shape of said non-straight curve are allowed within the scope of the present invention. Meander lines, random curves or space-filling curves, to name some particular cases, provide effective means for conforming the antenna behaviour. A thorough description of Space-Filling curves and antennas is disclosed in patent "*Space-Filling Miniature Antennas*"
- 20 (Patent Publication No. WO01/54225).

- Although patent publications WO01/22528 and WO01/54225 disclose some general configurations for multiband and miniature antennas, an improvement in terms of size, bandwidth and efficiency is obtained in some applications when
- 25 said multilevel antennas are set according to the present invention. Such an improvement is achieved mainly due to the combination of the multilevel structure in conjunction of the shaping of the gap between at least a couple of polygons on the multilevel structure. In some embodiments, the antenna is loaded with some capacitive elements to finely tune the antenna frequency
- 30 response.

In some particular embodiments of the present invention, the antenna is tuned to operate simultaneously at five bands, those bands being for instance

GSM900 (or AMPS), GSM1800, PCS1900, UMTS, and the 2.4GHz band for services such as for instance Bluetooth™, IEEE802.11b and HiperLAN. There is in the prior art one example of a multilevel antenna which covers four of said services, see embodiment (3) in Figure 1, but there is not an example of a design which is able to integrate all five bands corresponding to those services  
5      aforementioned into a single antenna.

The combination of said services into a single antenna device provides an advantage in terms of flexibility and functionality of current and future wireless  
10     devices. The resulting antenna covers the major current and future wireless services, opening this way a wide range of possibilities in the design of universal, multi-purpose, wireless terminals and devices that can transparently switch or simultaneously operate within all said services.

15

## **SUMMARY OF THE INVENTION**

The key point of the present invention consists of combining a multilevel structure for a multiband antenna together with an especial design on the shape of the gap or spacing between two polygons of said multilevel structure. A multilevel structure  
20     for an antenna device consists of a conducting structure including a set of polygons, all of said polygons featuring the same number of sides, wherein said polygons are electromagnetically coupled either by means of a capacitive coupling or ohmic contact, wherein the contact region between directly connected polygons  
25     is narrower than 50% of the perimeter of said polygons in at least 75% of said polygons defining said conducting multilevel structure. In this definition of multilevel structures, circles and ellipses are included as well, since they can be understood as polygons with a very large (ideally infinite) number of sides.

30     Some particular examples of prior-art multilevel structures for antennas are found in Figure 1: A thorough description on the shapes and features of multilevel antennas is disclosed in patent publication WO01/22528. For the particular case

of multilevel structure described in drawing (3), Figure 1 and in Figure 2, an analysis and description on the antenna behaviour is found in (J. Ollikainen, O. Kivekäs, A. Toropainen, P. Vainikainen, "Internal Dual-Band Patch Antenna for Mobile Phones", APS-2000 Millennium Conference on Antennas and  
5 Propagation, Davos, Switzerland, April 2000).

When the multiband behaviour of a multilevel structure is to be packed in a small antenna device, the spacing between the polygons of said multilevel structure is minimized. Drawings (3) and (4) in Figure 1 are some examples of multilevel  
10 structures where the spacing between conducting polygons (rectangles and squares in these particular cases) take the form of straight, narrow gaps.

In the present invention, at least one of said gaps is shaped in such a way that the whole gap length is increased yet keeping its size and the same overall antenna  
15 size. Such a configuration allows an effective tuning of the frequency bands of the antenna, such that with the same overall antenna size, said antenna can be effectively tuned simultaneously to some specific services, such as for instance the five frequency bands that cover the services AMPS, GSM900, GSM1800, PCS1900, UMTS, Bluetooth™, IEEE802.11b or HyperLAN.

20 Figures 3 to 7 show some examples of how the gap of the antenna can be effectively shaped according to the present invention. For instance, gaps (109), (110), (112), (113), (114), (116), (118), (120), (130), (131), and (132) are examples of non-straight gaps that take the form of a curved or branched line. All  
25 of them have in common that the resonant length of the multilevel structure is changed, changing this way the frequency behaviour of the antenna. Multiple configurations can be chosen for shaping the gap according to the present invention:

- a) A meandering curve.
- 30 b) A periodic curve.

- c) A branching curve, with a main longer curve with one or more added segments or branching curves departing from a point of said main longer curve.
- d) An arbitrary curve with 2 to 9 segments.
- 5 e) An space-filling curve.

An Space-Filling Curve (hereafter SFC) is a curve that is large in terms of physical length but small in terms of the area in which the curve can be included. More precisely, the following definition is taken in this document for a space-filling curve:

10 a curve composed by at least ten segments which are connected in such a way that each segment forms an angle with their neighbours, that is, no pair of adjacent segments define a larger straight segment, and wherein the curve can be optionally periodic along a fixed straight direction of space if, and only if, the period is defined by a non-periodic curve composed by at least ten connected segments

15 and no pair of said adjacent and connected segments defines a straight longer segment. Also, whatever the design of such SFC is, it can never intersect with itself at any point except the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the parts of the curve can become a closed loop). A space-filling curve can be fitted over a flat or curved surface, and

20 due to the angles between segments, the physical length of the curve is always larger than that of any straight line that can be fitted in the same area (surface) as said space-filling curve. Additionally, to properly shape the gap according to the present invention, the segments of the SFC curves included in said multilevel structure must be shorter than a tenth of the free-space operating wavelength.

25

It is interesting noticing that, even though ideal fractal curves are mathematical abstractions and cannot be physically implemented into a real device, some particular cases of SFC can be used to approach fractal shapes and curves, and therefore can be used as well according to the scope and spirit of the present

30 invention.

The advantages of the antenna design disclosed in the present invention are:

(a) The antenna size is reduced with respect to other prior-art multilevel antennas.

(b) The frequency response of the antenna can be tuned to five frequency bands that cover the main current and future wireless services (among  
5 AMPS, GSM900, GSM1800, PCS1900, Bluetooth™, IEEE802.11b and HiperLAN).

Those skilled in the art will notice that current invention can be applied or combined to many existing prior-art antenna techniques. The new geometry can  
10 be, for instance, applied to microstrip patch antennas, to Planar Inverted-F antennas (PIFAs), to monopole antennas and so on. Figures 6 and 7 describe some patch of PIFA like configurations. It is also clear that the same antenna geometry can be combined with several ground-planes and radomes to find applications in different environments: handsets, cellular phones and general  
15 handheld devices; portable computers (Palmtops, PDA, Laptops,...), indoor antennas (WLAN, cellular indoor coverage), outdoor antennas for microcells in cellular environments, antennas for cars integrated in rear-view mirrors, stop-lights, bumpers and so on.

20 In particular, the present invention can be combined with the new generation of ground-planes described in the PCT application entitled "Multilevel and Space-Filling Ground-planes for Miniature and Multiband Antennas", which describes a ground-plane for an antenna device, comprising at least two conducting surfaces, said conducting surfaces being connected by at least a conducting strip, said strip  
25 being narrower than the width of any of said two conducting surfaces.

When combined to said ground-planes, the combined advantages of both inventions are obtained: a compact-size antenna device with an enhanced bandwidth, frequency behaviour, VSWR, and efficiency.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 describes four particular examples (1), (2), (3), (4) of prior-art multilevel geometries for multilevel antennas.

5

Figure 2 describes a particular case of a prior-art multilevel antenna formed with eight rectangles (101), (102), (103), (104), (105), (106), (107), and (108).

Figure 3 drawings (5) and (6) show two embodiments of the present invention.

10 Gaps (109) and (110) between rectangles (102) and (104) of design (3) are shaped as non-straight curves (109) according to the present invention.

Figure 4 shows three examples of embodiments (7), (8), (9) for the present invention. All three have in common that include branching gaps (112), (113),

15 (114), (130), (118), (120).

Figure 5 shows two particular embodiments (10) and (11) for the present invention. The multilevel structure consists of a set of eight rectangles as in the case of design (3), but rectangle (108) is placed between rectangle (104) and (106). Non-straight, shaped gaps (131) and (132) are placed between polygons (102) and (104).

20

Figure 6 shows three particular embodiments (12), (13), (14) for three complete antenna devices based on the combined multilevel and gap-shaped structure disclosed in the present invention. All three are mounted in a rectangular ground-plane such that the whole antenna device can be, for instance, integrated in a handheld or cellular phone. All three include two-loading capacitors (123) and (124) in rectangle (103), and a loading capacitor (124) in rectangle (101). All of them include two short-circuits (126) on polygons (101) and (103) and are fed by

25

30



Figure 7 shows a particular embodiment (15) of the invention combined with a particular case of Multilevel and Space-Filling ground-plane according to the PCT application entitled "Multilevel and Space-Filling Ground-planes for Miniature and Multiband Antennas". In this particular case, ground-plane (125) is formed by two conducting surfaces (127) and (129) with a conducting strip (128) between said two conducting surfaces.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

10

Drawings (5) and (6) in Figure 3 show two particular embodiments of the multilevel structure and the non-linear gap according to the present invention. The multilevel structure is based on design (3) in Figure 2 and it includes eight conducting rectangles: a first rectangle (101) being capacitively coupled to a second rectangle (102), said second rectangle being connected at one tip to a first tip of a third rectangle (103), said third rectangle being substantially orthogonal to said second rectangle, said third rectangle being connected at a second tip to a first tip of a fourth rectangle (104), said fourth rectangle being substantially orthogonal to said third rectangle and substantially parallel to said second rectangle, said fourth rectangle being connected at a second tip to a first tip of a fifth rectangle (105), said fifth rectangle being substantially orthogonal to said fourth rectangle and substantially parallel to said third rectangle, said fifth rectangle being connected at a second tip to a first tip of a sixth rectangle (106), said sixth rectangle being substantially orthogonal to said fifth rectangle and substantially parallel to said fourth rectangle, said sixth rectangle being connected at a second tip to a first tip of a seventh rectangle (107), said seventh rectangle being substantially orthogonal to said sixth rectangle and parallel to said fifth rectangle, said seventh rectangle being connected to a first tip of an eighth rectangle (108), said eighth rectangle being substantially orthogonal to said seventh rectangle and substantially parallel to said sixth rectangle.

30

Both designs (5) and (6) include a non-straight gap (109) and (110) respectively, between second (102) and fourth (104) polygons. It is clear that the shape of the gap and its physical length can be changed. This allows a fine tuning of the antenna to the desired frequency bands in case the conducting multilevel structure is supported by a high permittivity substrate.

The advantage of designs (5) and (6) with respect to prior art is that they cover five bands that include the major existing wireless and cellular systems (among AMPS, GSM900, GSM1800, PCS1900, UMTS, Bluetooth™, IEEE802.11b, HiperLAN).

Three other embodiments for the invention are shown in Figure 4. All three are based on design (3) but they include two shaped gaps. These two gaps are placed between rectangle (101) and rectangle (102), and between rectangle (102) and (104) respectively. In these examples, the gaps take the form of a branching structure. In embodiment (7) gaps (112) and (113) include a main gap segment plus a minor gap-segment (111) connected to a point of said main gap segment. In embodiment (8), gaps (114) and (116) include respectively two minor gap-segments such as (115). Many other branching structures can be chosen for said gaps according to the present invention, and for instance more convoluted shapes for the minor gaps as for instance (117) and (119) included in gaps (118) and (120) in embodiment (9) are possible within the scope and spirit of the present invention.

Although design in Figure 3 has been taken as an example for embodiments in Figures 3 and 4, other eight-rectangle multilevel structures, or even other multilevel structures with a different number of polygons can be used according to the present invention, as long as at least one of the gaps between two polygons is shaped as a non-straight curve. Another example of an eight-rectangle multilevel structure is shown in embodiments (10) and (11) in Figure 5. In this case, rectangle (108) is placed between rectangles (106) and (104) respectively. This contributes in reducing the overall antenna size with respect to design (3). Length

of rectangle (108) can be adjusted to finely tune the frequency response of the antenna (different lengths are shown as an example in designs (10) and (11)) which is useful when adjusting the position of some of the frequency bands for future wireless services, or for instance to compensate the effective dielectric permittivity when the structure is built upon a dielectric surface.

Figure 6 shows three examples of embodiments (12), (13), and (14) where the multilevel structure is mounted in a particular configuration as a patch antenna. Designs (5) and (7) are chosen as a particular example, but it is obvious that any other multilevel structure can be used in the same manner as well, as for instance in the case of embodiment (14). For the embodiments in Figure 6, a rectangular ground-plane (125) is included and the antenna is placed at one end of said ground-plane. These embodiments are suitable, for instance, for handheld devices and cellular phones, where additional space is required for batteries and circuitry. The skilled in the art will notice, however, that other ground-plane geometries and positions for the multilevel structure could be chosen, depending on the application (handsets, cellular phones and general handheld devices; portable computers such as Palmtops, PDA, Laptops, indoor antennas for WLAN, cellular indoor coverage, outdoor antennas for microcells in cellular environments, antennas for cars integrated in rear-view mirrors, stop-lights, and bumpers are some examples of possible applications) according to the present invention.

All three embodiments (12), (13), (14) include two-loading capacitors (123) and (124) in rectangle (103), and a loading capacitor (124) in rectangle (101). All of them include two short-circuits (126) on polygons (101) and (103) and are fed by means of a pin or coaxial probe in rectangles (102) or (103). Additionally, a loading capacitor at the end of rectangle (108) can be used for the tuning of the antenna.

It will be clear to those skilled in the art that the present invention can be combined in a novel way to other prior-art antenna configurations. For instance, the new generation of ground-planes disclosed in the PCT application entitled

"Multilevel and Space-Filling Ground-planes for Miniature and Multiband Antennas" can be used in combination with the present invention to further enhance the antenna device in terms of size, VSWR, bandwidth, and/or efficiency. A particular case of ground-plane (125) formed with two conducting surfaces (127) and (129), said surfaces being connected by means of a conducting strip (128), is shown as an example in embodiment (15).

The particular embodiments shown in Figures 6 and 7 are similar to PIFA configurations in the sense that they include a shorting-plate or pin for a patch antenna upon a parallel ground-plane. The skilled in the art will notice that the same multilevel structure including the non-straight gap can be used in the radiating elements of other possible configurations, such as for instance, monopoles, dipoles or slotted structures.

It is important to stress that the key aspect of the invention is the geometry disclosed in the present invention. The manufacturing process or material for the antenna device is not a relevant part of the invention and any process or material described in the prior-art can be used within the scope and spirit of the present invention. To name some possible examples, but not limited to them, the antenna could be stamped in a metal foil or laminate; even the whole antenna structure including the multilevel structure, loading elements and ground-plane could be stamped, etched or laser cut in a single metallic surface and folded over the short-circuits to obtain, for instance, the configurations in Figures 6 and 7. Also, for instance, the multilevel structure might be printed over a dielectric material (for instance FR4, Rogers®, Arlon® or Cuclad®) using conventional printing circuit techniques, or could even be deposited over a dielectric support using a two-shot injecting process to shape both the dielectric support and the conducting multilevel structure.

**CLAIMS**

1.- A multiband antenna characterized in that at least two polygons of the multilevel structure are spaced by means of a non-straight gap in such a way that  
5 the whole gap length is increased yet keeping its size.

2.- A multiband antenna according to claim 1, wherein the shape of said non-straight gap is a curve composed by 2 to 9 segments, wherein said segments form a non-flat angle with adjacent segments.  
10

3.- A multiband antenna according to claim 1, wherein the shape of said non-straight gap is a space-filling curve.

4.- A multiband antenna according to claim 1, wherein the shape of said non-straight gap is a meandering curve.  
15

5.- A multiband antenna according to claim 1, wherein said non-straight gap includes at least a first segment and a second shorter segment connected at a point of said first straight segment.  
20

6.- A multiband antenna according to claim 1, wherein the shape of said non-straight gap is a periodic curve.

7.- A multiband antenna according to claims 1, 2, 3, 4, 5, or 6, wherein the multilevel structure is composed by at least eight rectangles, a first rectangle  
25 being capacitively coupled to a second rectangle, said second rectangle being connected at one tip to a first tip of a third rectangle, said third rectangle being substantially orthogonal to said second rectangle, said third rectangle being connected at a second tip to a first tip of a fourth rectangle, said fourth rectangle  
30 being substantially orthogonal to said third rectangle and substantially parallel to said second rectangle, said fourth rectangle being connected at a second tip to a first tip of a fifth rectangle, said fifth rectangle being substantially orthogonal to

said fourth rectangle and substantially parallel to said third rectangle, said fifth rectangle being connected at a second tip to a first tip of a sixth rectangle, said sixth rectangle being substantially orthogonal to said fifth rectangle and substantially parallel to said fourth rectangle, said sixth rectangle being connected  
5 at a second tip to a first tip of a seventh rectangle, said seventh rectangle being substantially orthogonal to said sixth rectangle and parallel to said fifth rectangle, said seventh rectangle being connected to a first tip of an eighth rectangle, said eighth rectangle being substantially orthogonal to said seventh rectangle and substantially parallel to said sixth rectangle.

10

8.- A multiband antenna according to claims 1, 2, 3, 4, 5, or 6, wherein the multilevel structure is composed by at least eight rectangles, a first rectangle being capacitively coupled to a second rectangle, said second rectangle being connected at one tip to a first tip of a third rectangle, said third rectangle being  
15 substantially orthogonal to said second rectangle, said third rectangle being connected at a second tip to a first tip of a fourth rectangle, said fourth rectangle being substantially orthogonal to said third rectangle and substantially parallel to said second rectangle, said fourth rectangle being connected at a second tip to a first tip of a fifth rectangle, said fifth rectangle being substantially orthogonal to  
20 said fourth rectangle and substantially parallel to said third rectangle, said fifth rectangle being connected at a second tip to a first tip of a sixth rectangle, said sixth rectangle being substantially orthogonal to said fifth rectangle and substantially parallel to said fourth rectangle, said sixth rectangle being connected at a second tip to a first tip of a seventh rectangle, said seventh rectangle being  
25 substantially orthogonal to said sixth rectangle and parallel to said fifth rectangle, said seventh rectangle being connected to a first tip of an eighth rectangle, said eighth rectangle being substantially orthogonal to said seventh rectangle and substantially parallel to said sixth rectangle, and wherein said eighth rectangle is placed between said fourth and sixth rectangles.

30

9.- A multiband antenna to operate at five bands according to claims 1, 2, 3, 4, 5, 6, 7, or 8 wherein the non-straight gap is placed between said second and fourth rectangle.

5 10.- A multiband antenna to operate at five bands according to claims 7, 8, or 9, wherein the antenna includes at least a first and a second short-circuits between the eight-rectangle multilevel structure and the ground-plane, a first short-circuit being connected to one edge on the tip of the first rectangle of said multilevel structure and a second short-circuit being connected at one edge of the third  
10 rectangle of said multilevel structure.

11.- A multiband antenna to operate at five bands according to claims 7, 8, 9, or 10, wherein the antenna includes at least a first and a second capacitive load on the multilevel structure, said capacitive load consisting on a conducting strip, said  
15 conducting strip being connected at one edge of said multilevel structure and being placed orthogonally to said multilevel structure between said multilevel structure and the ground-plane.

12.- A multiband antenna to operate at five bands according to claim 11, wherein  
20 the antenna includes at least a first capacitive load connected at the second tip of the eighth rectangle.

13.- A multiband antenna to operate at five bands according to claims 11 or 12, wherein the antenna includes at least three capacitive loads, a first capacitive  
25 load being connected at one edge of the first rectangle of said multilevel structure, second and third capacitive loads connected at one edge of the third rectangle of said multilevel structure, wherein the second capacitive load is placed closer to the second rectangle while the third capacitive load is placed closer to the third rectangle.

14

14.- A multiband antenna to operate at five bands according to claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 13, wherein the multilevel structure is placed at one end of a rectangular ground-plane and parallel to said ground-plane.

5 15.- A multiband antenna to operate at five bands according to claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, or 14, wherein the antenna is fed by means of a straight pin to a point on the second or third rectangle of said multilevel structure and wherein the antenna is matched below a  $VSWR < 3$  at the frequency bands of the following five wireless services: GSM900, GSM1800, PCS1900, UMTS and  
10 2.4GHz.

16.- A multiband antenna to operate at five bands according to claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15, wherein the multilevel structure is placed over a Multilevel and Space-Filling Ground-Plane which includes at least two  
15 conducting surfaces, said conducting surfaces being connected by at least a conducting strip, said strip being narrower than the width of any of said two conducting surfaces.

17.- A multiband antenna to operate at five bands according to claims 1, 2, 3, 4,  
20 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or 16, wherein the multilevel structure is placed over a rectangular ground-plane, said ground-plane including at least one slot at least one of its edges.

18.- A multiband antenna to operate at five bands according to any of the  
25 preceding claims wherein the antenna is placed inside a cellular phone or handheld wireless terminal.

30



1/7

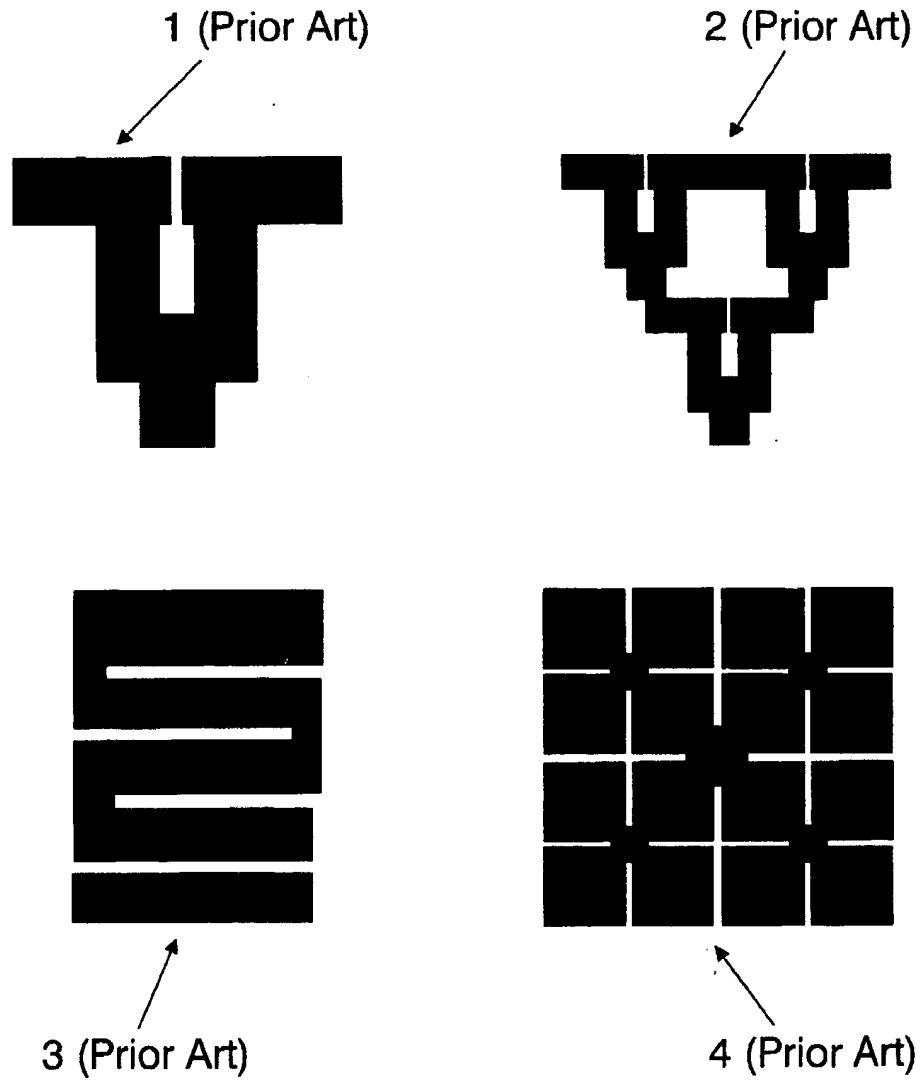


FIG.1

2/7

3 (Prior Art)



3 (Prior Art)

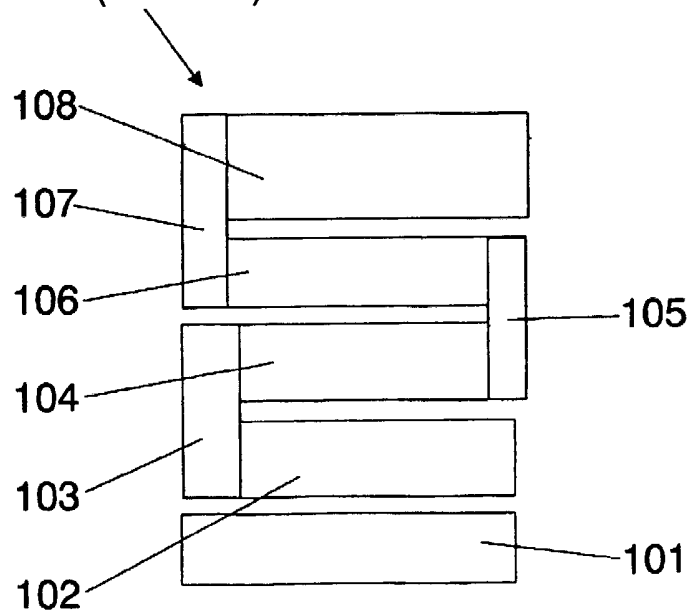


FIG.2

3/7

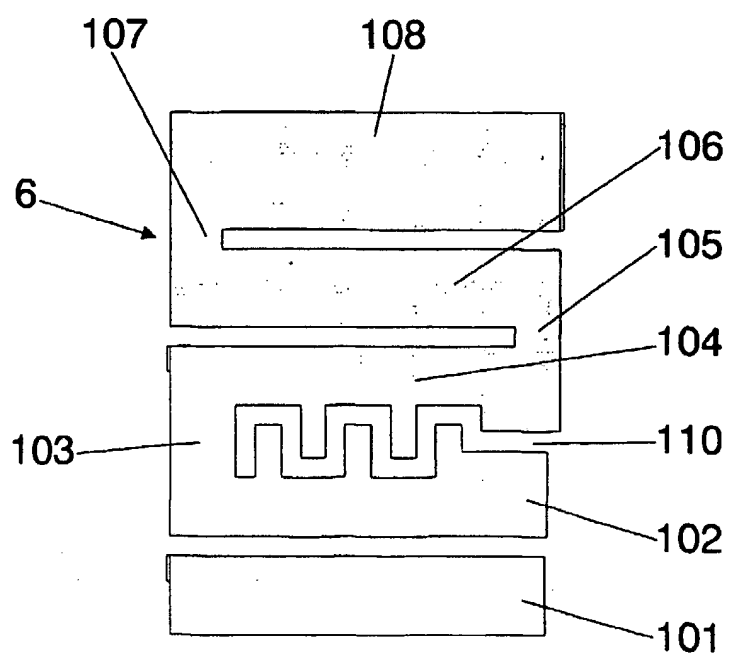
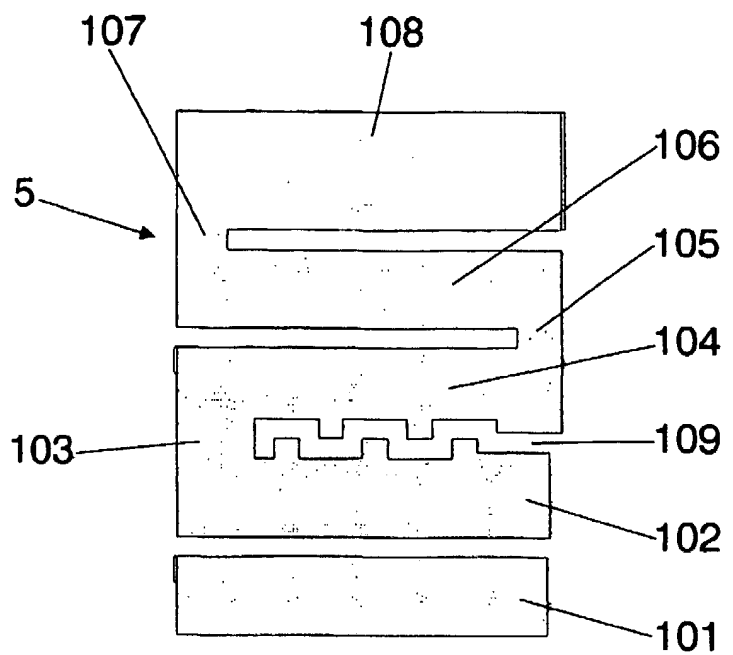


FIG.3

4/7

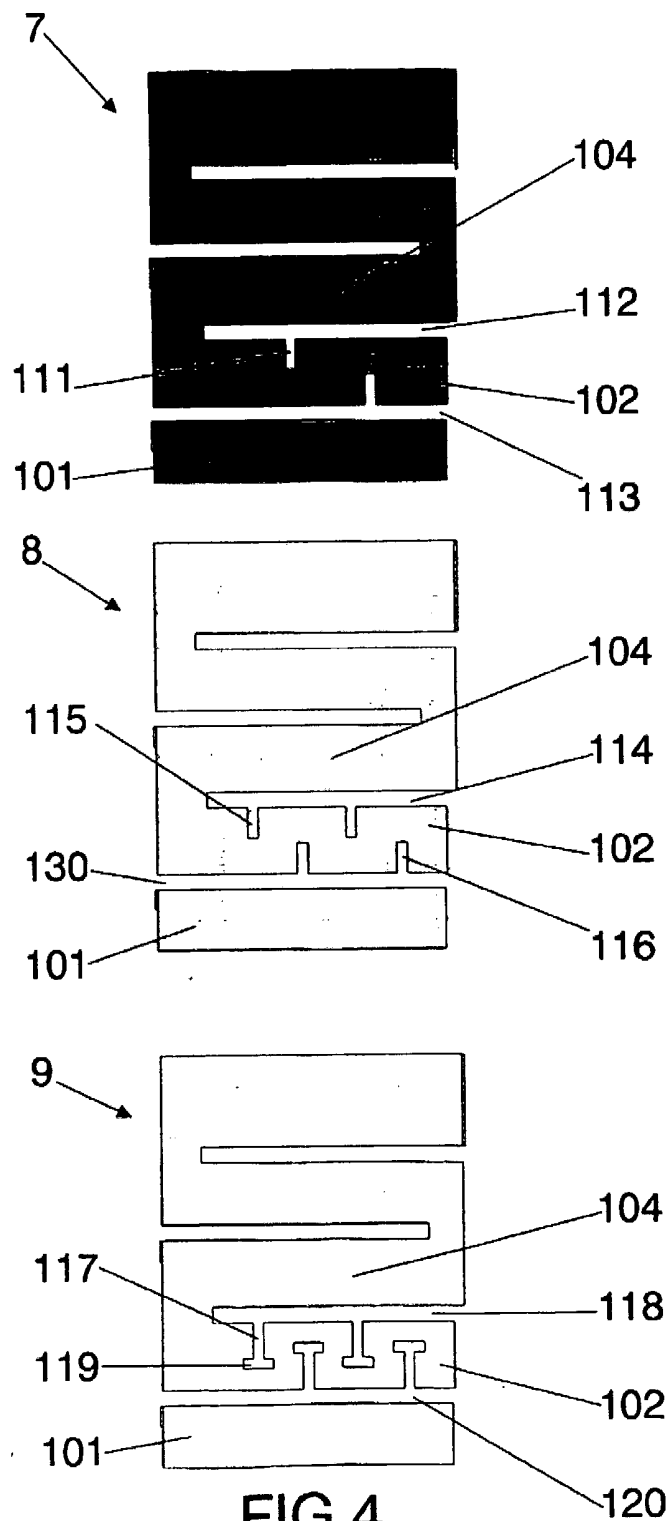


FIG.4

5/7

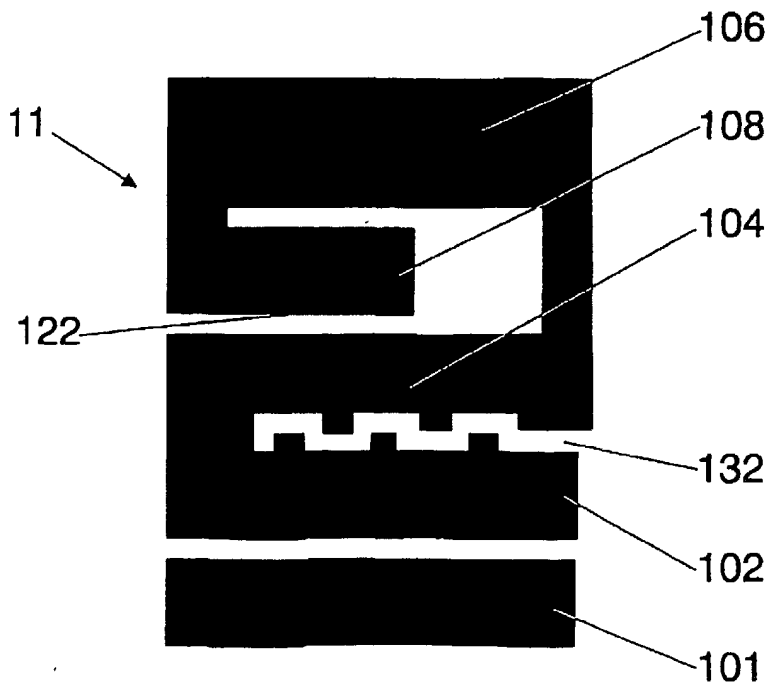
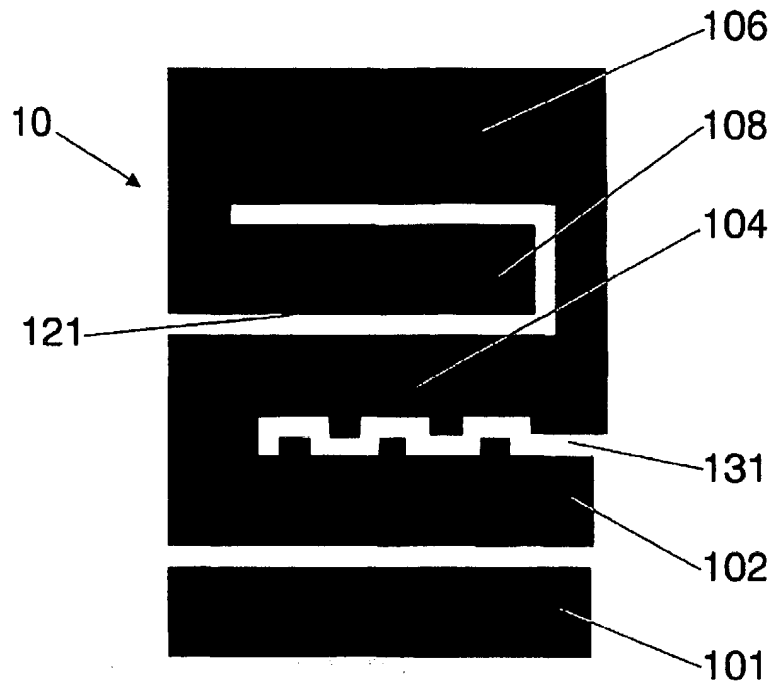


FIG.5

SUBSTITUTE SHEET (RULE 26)

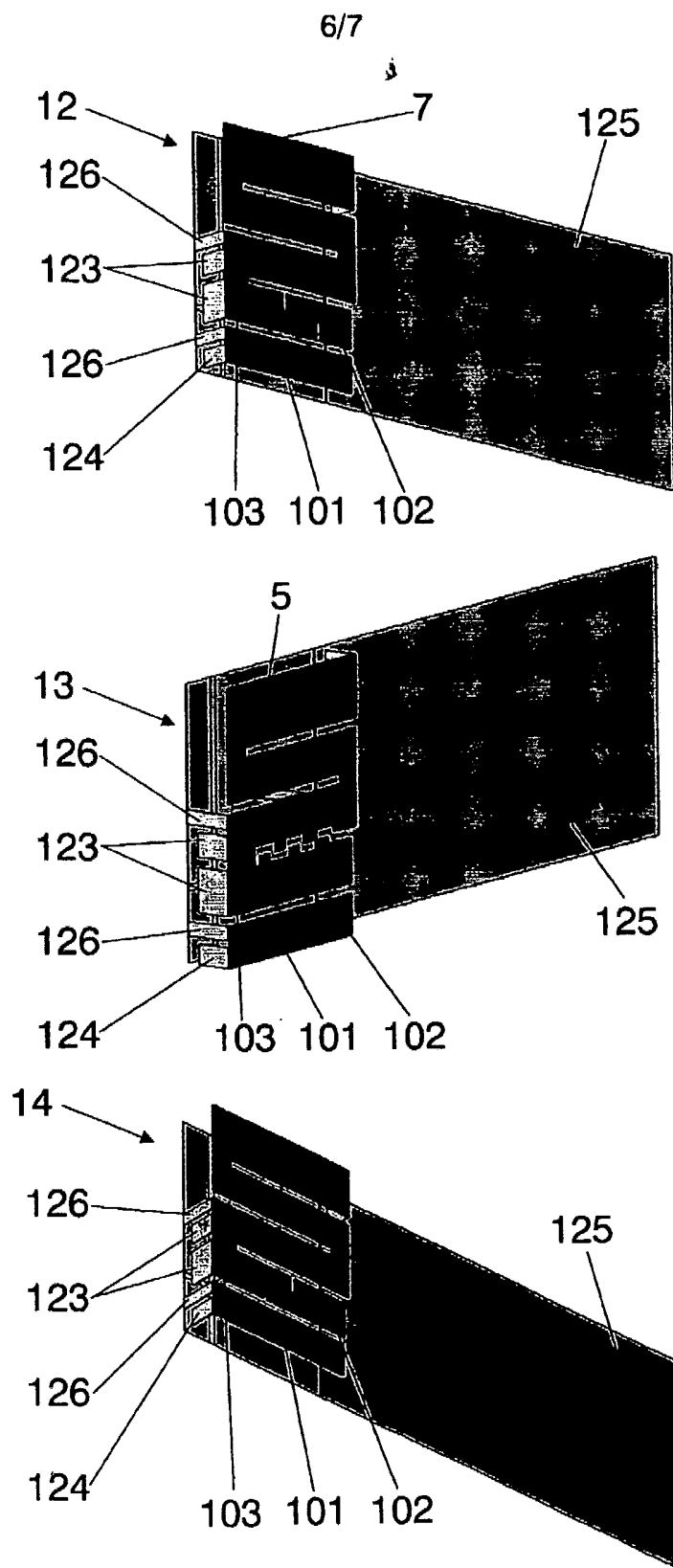


FIG.6

7/7

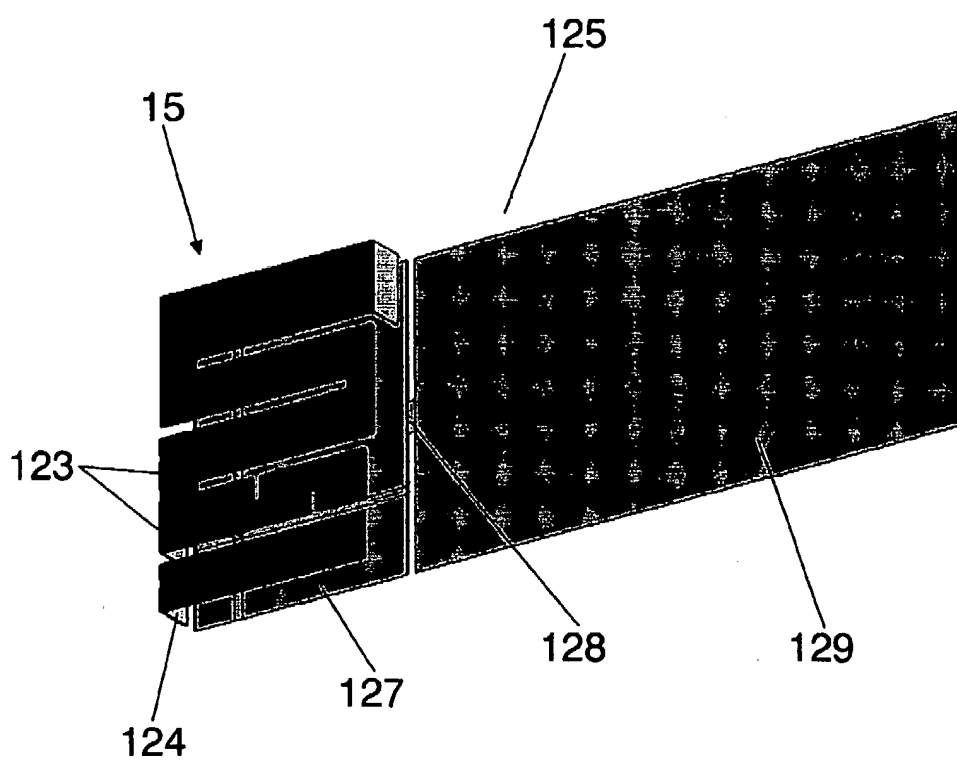


FIG. 7

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/EP 01/11912

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01Q9/04 H01Q1/24 H01Q5/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 13, 30 November 1998 (1998-11-30) & JP 10 209744 A (MATSUSHITA ELECTRIC WORKS LTD), 7 August 1998 (1998-08-07)	1-6, 14-18
Y	abstract; figure 4	7-13
X	EP 0 997 974 A (LK PRODUCTS OY) 3 May 2000 (2000-05-03) abstract; figures 8A-8I	1-6
X	WO 01 08257 A (INTEGRA ANTENNAS LTD ; AVANTEGO AB (SE); ROWELL CORBETT (US)) 1 February 2001 (2001-02-01) abstract; figures 3,4	1-6
	-/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents:

\*A\* document defining the general state of the art which is not considered to be of particular relevance

\*E\* earlier document but published on or after the international filing date

\*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

\*O\* document referring to an oral disclosure, use, exhibition or other means

\*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*A\* document member of the same patent family

Date of the actual completion of the international search

22 May 2002

Date of mailing of the international search report

31/05/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Johansson, R



## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/EP 01/11912

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01 54225 A (FRACTUS S A ; ANGUERA PROS JAIME (ES); PUENTE BALIARDA CARLES (ES);) 26 July 2001 (2001-07-26) page 16, line 1 - line 11; figure 15 ---	1-6
X	EP 0 929 121 A (NOKIA MOBILE PHONES LTD) 14 July 1999 (1999-07-14) abstract; figures 6,7 ---	1-6
X	EP 0 892 459 A (NOKIA MOBILE PHONES LTD) 20 January 1999 (1999-01-20) abstract; figure 11 ---	1-6
Y		10-13
X	WO 00 36700 A (ERICSSON TELEFON AB L M) 22 June 2000 (2000-06-22) abstract; figures 4-6D ---	1-6
X	EP 1 128 466 A (FILTRONIC LK OY) 29 August 2001 (2001-08-29) figures 3-4D ---	1-6
Y	WO 96 27219 A (UNIV HONG KONG CHINESE) 6 September 1996 (1996-09-06) abstract; figures 1-4A ---	7-9
Y	EP 0 942 488 A (MURATA MANUFACTURING CO) 15 September 1999 (1999-09-15) abstract; figures 1,3 -----	7-9

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 01/11912

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 10209744	A	07-08-1998	NONE	
EP 0997974	A	03-05-2000	FI 105061 B1 AT 211861 T CN 1260606 A DE 69900773 D1 DK 997974 T3 EP 0997974 A1 US 6366243 B1	31-05-2000 15-01-2002 19-07-2000 28-02-2002 04-03-2002 03-05-2000 02-04-2002
WO 0108257	A	01-02-2001	AU 6331600 A WO 0108257 A1	13-02-2001 01-02-2001
WO 0154225	A	26-07-2001	WO 0154225 A1 AU 3150000 A	26-07-2001 31-07-2001
EP 0929121	A	14-07-1999	US 5929813 A BR 9900013 A EP 0929121 A1 EP 0929115 A1 JP 2000004116 A US 6025802 A US 6054954 A	27-07-1999 21-12-1999 14-07-1999 14-07-1999 07-01-2000 15-02-2000 25-04-2000
EP 0892459	A	20-01-1999	FI 972897 A EP 0892459 A1 FI 981571 A US 6140966 A	09-01-1999 20-01-1999 09-01-1999 31-10-2000
WO 0036700	A	22-06-2000	US 6343208 B1 AU 3092500 A DE 19983824 T0 GB 2363911 A WO 0036700 A1	29-01-2002 03-07-2000 07-03-2002 09-01-2002 22-06-2000
EP 1128466	A	29-08-2001	FI 20000437 A CN 1316797 A EP 1128466 A2 US 2001048391 A1	24-08-2001 10-10-2001 29-08-2001 06-12-2001
WO 9627219	A	06-09-1996	WO 9627219 A1	06-09-1996
EP 0942488	A	15-09-1999	JP 3252786 B2 JP 11312923 A EP 0942488 A2 US 6147650 A	04-02-2002 09-11-1999 15-09-1999 14-11-2000